345-kV CABLE SYSTEMS FOR AN UNDERGROUND CROSSING OF THE NAMEKAGON RIVER

OCTOBER 18, 1999

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1.0 INTRODUCTION:

1.1 Scope

Minnesota Power Company requested Power Delivery Consultants, Inc. to evaluate and provide background information on underground cable systems and their construction methods, for a proposed 345-kV overhead transmission line that may cross the Namekagon River near Trego, Wisconsin. Cable distance would be determined by the transition station locations on either side of the river. We assumed a 1700-foot length for our evaluation.

This report summarizes the evaluation of different cable types that could be considered for the crossing, their construction methods, and the estimated costs.

The proposed 345-kV overhead line is rated 1200 MVA. Any underground cable system would not be permitted to reduce the rated power transfer of the overhead line.

Since a failure on a cable may take several weeks to repair – or even several months if new cable must be obtained – our design assumed that the full 1200 MVA could be carried with a cable out of service. The cable system therefore required three separate lines. Two lines can carry 1200 MVA for the 1000 hours (42 days) that we assumed it would take to repair a failed cable.

1.2 Summary

A high-pressure liquid-filled (HPLF) cable system is the U.S standard for 345-kV cables and could meet the project requirements. Three 8-5/8 inch diameter steel pipes would be required, each pipe containing three paper-insulated copper-conductor cables. This evaluation assumed the river crossing would be installed by horizontal directional drilling and the sections on either side would be installed using conventional trenching. Transition stations for connection to the overhead line would be required at each end of the cable circuits.

The estimated cost of the underground cable installation and transition stations adjacent to the 161-kV overhead line right-of-way, is about $6 million.

1.3 Project Location

The proposed 345-kV overhead line may cross the Namekagon River alongside the right-of-way for an existing 161-kV overhead line, adjacent to a right-of-way for Lakehead Pipe Line Co's petroleum pipes. Figure 1-1 shows the approximate location. Another river crossing location is being considered, near a railroad bridge approximately ½ mile from the pipeline crossing.

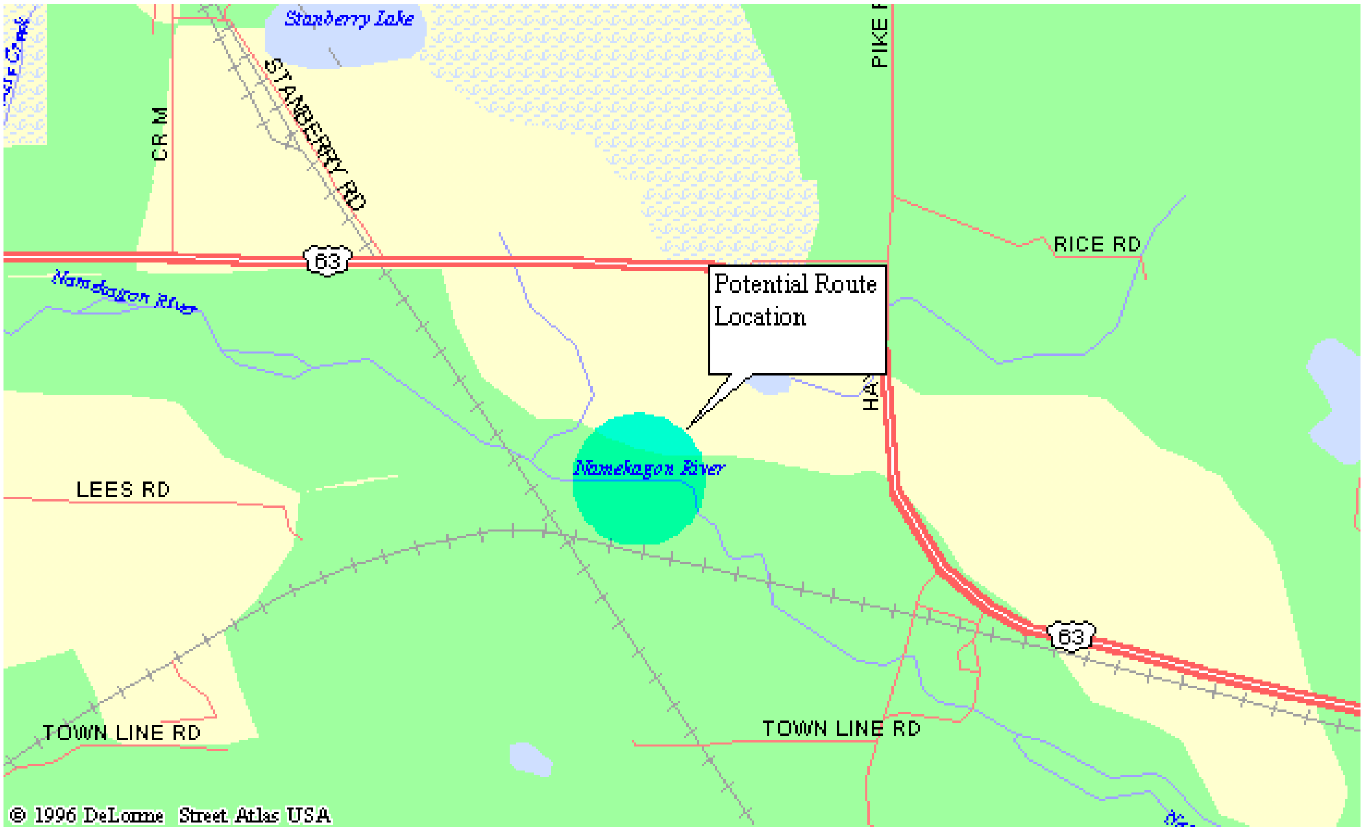

Figure 1-1. Potential route location

2.0 CABLE SYSTEM TYPES EVALUATED

2.1 Cable System Types

Four cable types can be considered for 345-kV operation. These cables, and their principal characteristics, are summarized below:

High-pressure Liquid-filled (HPLF) pipe-type cable. This is the cable used in the United States for all 345-kV operation except for a very small amount of SF_6 bus. Dozens of circuits have been installed in metropolitan areas – totaling a few hundred miles, in comparison to the approximately 50,000 miles of 345-kV overhead line. HPLF cable has a long, excellent operating history. Its use in recent years has diminished, however, because of concerns about possible leaks of dielectric liquid from the pipes. HPLF cable requires a pressurizing plant with a footprint approximately 10 ft by 20 ft, and the plant needs a reliable 10 kW power supply, plus alarm connections.

Self-contained Liquid-filled cable. SCLF cable has been used in this country and overseas for more than 70 years. Although testing was performed in the 1960's at 345 kV, it has never been used at that voltage. It is more maintenance-intensive than other cable types because of the distributed liquid reservoirs and need for an alarm system covering all of the reservoirs – which are typically distributed along the length of the cable circuit. SCLF cable has been replaced with extruded-dielectric cable worldwide, except for submarine crossings where the excellent reliability and long splice-free lengths make it ideal.

Extruded-dielectric cable. This cable, typically insulated with crosslinked polyethylene, is becoming the U.S. standard up to 138 kV. There have been only four installations in this country at 230 kV, but extruded-dielectric cable is in use for more than twenty years in other parts of the world for 220-kV operation. There have been a few commercial installations overseas at 400 kV. We know of no 345-kV cable installations.

SF_6 bus (Compressed Gas-insulated Transmission Line) This system resembles substation bus. Its use is limited to short lengths and high power transfers, for lines installed above-ground or in troughs. There have been several 345-kV installations, of lengths up to 1000 feet or so.

2.2 Recommended Cable Type

We investigated the advantages and disadvantages of each of these cable types for a Namekagon River crossing, and determined that the HPLF pipe-type cable would be the preferred type. Although great care must be taken during installation and operation to make sure there is no dielectric liquid leakage, this type is the U.S. standard at 345 kV, it is a very rugged system, and it has an excellent operating history.

A further description of the HPLF system is given below:

2.3 *High-pressure Liquid-filled (HPLF) Pipe-type Cables*

General

In the HPLF pipe-type cable system (Fig. 2-1) the three cables are pulled into a steel pipe which is typically 8-5/8 inches outside diameter. The pipe generally has a 1/4-inch wall (although 3/8 inches is often used for water crossings) and an outer polyethylene corrosion protection covering.

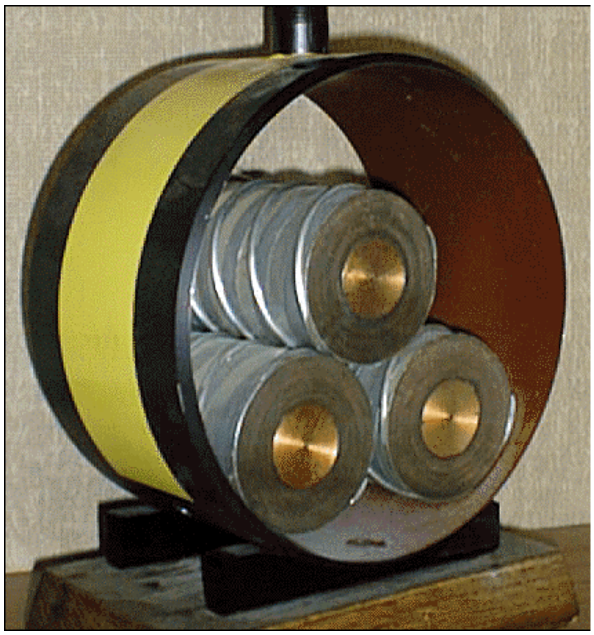

Figure 2-1. High-pressure liquid-filled pipe-type cable.

The pipe is typically filled with a polybutene or polybutene / alkylbenzene dielectric liquid mixture. These are both petroleum-based, highly-refined synthetic insulating liquids. Nominal operating pressure is 200 psi.

Accessories

A HPLF pipe-type cable system includes the following accessories:

- Splices: The cable can be supplied and installed in 2,000 – 3,000 foot lengths. Splices must be installed to connect adjoining cable sections. The copper conductors are joined with a special connector, and the insulation is reestablished over the connector with a gentle profile to give smooth grading of electric fields. A steel casing is placed over the completed splice. The splice assembly is placed in a manhole to provide controlled conditions in making the splice, liquid sampling, and rapid access in case repair is required. The complete splicing operation takes about a week for a three-phase splice. Figure 2-2 shows a 345-kV HPLF splice in a manhole.

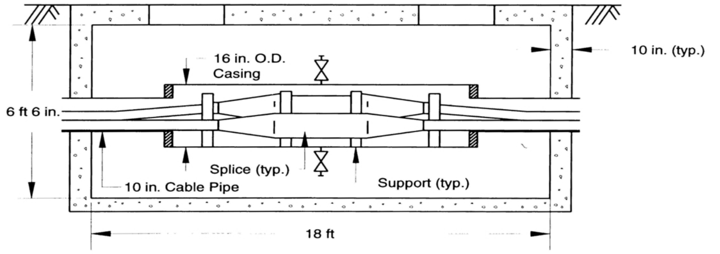

Figure 2-2. Typical HPLF cable splice

A single splice for each of the cables circuits would probably be required for the Namekagon River crossing. Even though the 1700-foot distance could be installed splice-free, every pipe-type cable system must have at least one splice to permit proper connection of the three individual phases to their respective terminations.

- Terminations: An HPLF pipe-type termination consists of a single conductor cable, a stress relief cone and an insulating enclosure (pothead). The three single-phase potheads are spaced apart with the necessary electrical clearances, typically about 15 feet at 345 kV. The transition from three conductors in a single steel pipe, to one conductor each in it's own non-magnetic metallic pipe (typically stainless steel) is accomplished using a special casing known as a spreaderhead or trifurcator. Figure 2-3 shows a typical HPLF cable termination.

(These two figures, plus several other figures in this report, are reproduced from the EPRI *Underground Transmission Systems Reference Book.)*

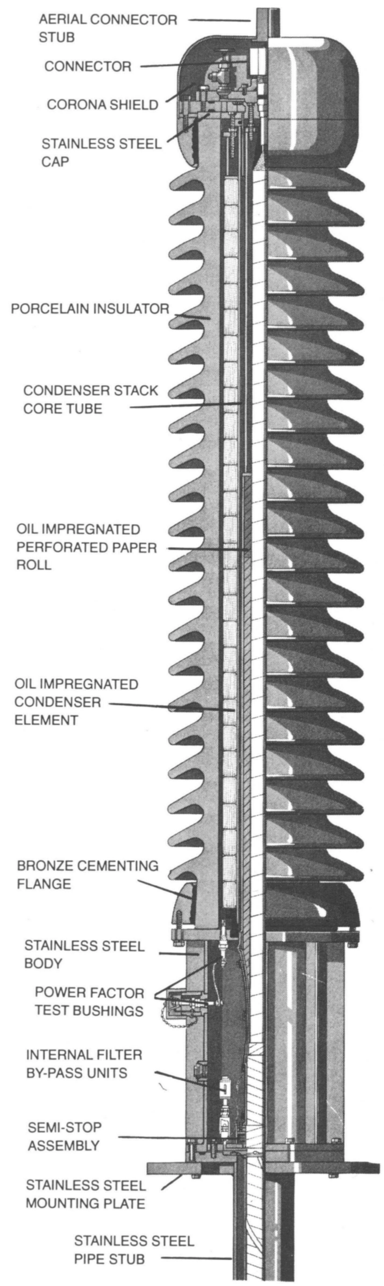

Figure 2-3. Typical HPLF termination

- Corrosion Coating and Cathodic Protection: are provided to reduce the possibility of corrosion of the steel pipe. A rectifier is connected to the pipe to provide the required negative 0.85 V that insures that current flows to the pipe if the coating is damaged. If current flowed from the pipe to earth, metal would be removed and a corrosion pinhole would form. A polarization cell, or its solid-state equivalent, provides a path to ground for current that would flow on the pipe in event of a cable fault.

- Pressurizing Plants: are required to maintain the nominal 200-psi pressure over a range of system liquid volumes – which vary due to the thermal expansion and contraction from load changes on the circuit. The plant consists of a liquid storage tank which typically has a capacity in the range 2,000 - 12,000 gallons, pressurizing pumps controlled by pressure switches, pressure relief valves, alarms and other controls. Theoretically it is sufficient to have a single pumping plant placed at one end of a cable circuit but many utilities place a plant at each end so pressure can be maintained in case one plant is out of service. Figure 2-4 shows a typical pressurizing plant for outdoor use.

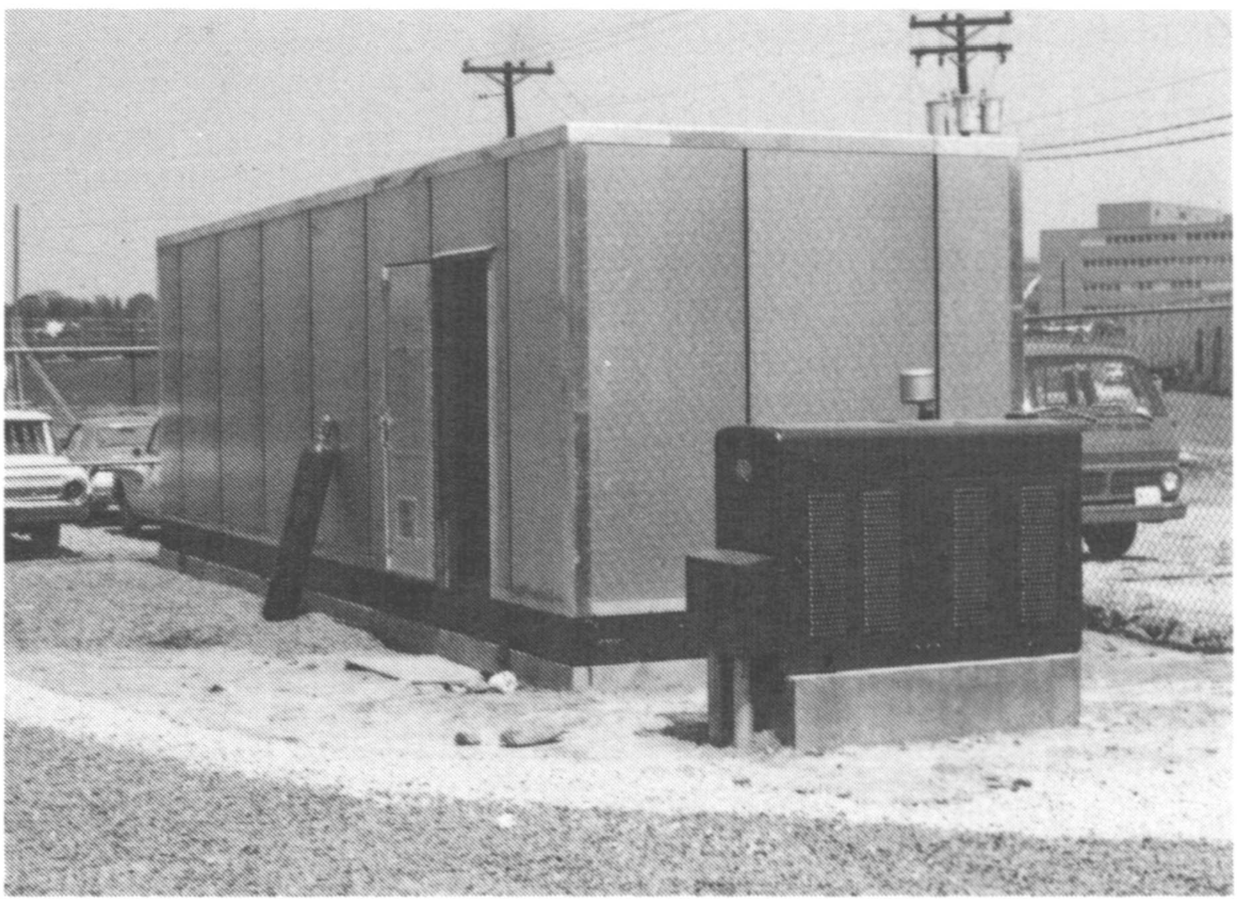

Figure 2-4. Typical pressurizing plant

3.0 CABLE SIZING, AMPACITY CALCULATIONS

3.1 General

We determined the number of circuits and cable sizes required to meet a firm 1200 MVA power transfer requirement. The contingency power transfer requirement determined a need for three lines. With the three circuits side-by-side, we assumed that one outside circuit failed, which is the most conservative assumption. Two adjacent circuits therefore could carry the full 1200 MVA power transfer until the failed cable could be repaired. We assumed a 1000-hour (42-day) repair time[1].

A copper conductor size of 3000 kcmil (approximately 1.9 inches diameter) would give the required 1200 MVA (2000 amperes) transfer on two circuits for the 1000 hours.

The section installed in the guided boring determines the conductor size. Heat transfer from the cable installed at a 40-foot depth is poorer than the heat transfer from a cable installed at a four-foot depth.

[1] Con Edison, which operates the world's most extensive 345-kV cable system, states a typical repair time of about one month. We added another ten days because of the remoteness of the Namekagon River crossing and the time it would take to get experienced crews and equipment to the site.

4.0 TRENCH AND BORE CONFIGURATIONS

This section of the report describes the configuration of trenches and bores that could be used for the Namekagon River crossing and adjacent land sections. Typical cross-sections are provided; detailed circuit design may change the cross-sections slightly.

The 1997 oil pipe installation by Lakehead Pipe Line Co. (Lakehead) across the Namekagon River near the potential cable crossing, was directionally drilled. We assumed that any cable crossing would be directionally drilled, as well. Open trenching would probably be used for a portion of the land cable. It may be technically feasible to drill the entire 1700 feet, but a 900-foot bore is less costly and has less potential for problems during drilling.

4.1 Directional Drilling for Water Crossing

Figure 4-1 shows a cross-section for pipe-type cables installed by directional drilling (also commonly called guided boring). Casing and bore diameters are shown for the HPLF cables, which require an 8-5/8 inch cable pipe, a 12-inch casing, and an 18-inch boring. The right-hand boring also contains communications ducts, so a 14-inch casing and a 20-inch boring are shown. The length of the bore would need to be approximately 900 feet.

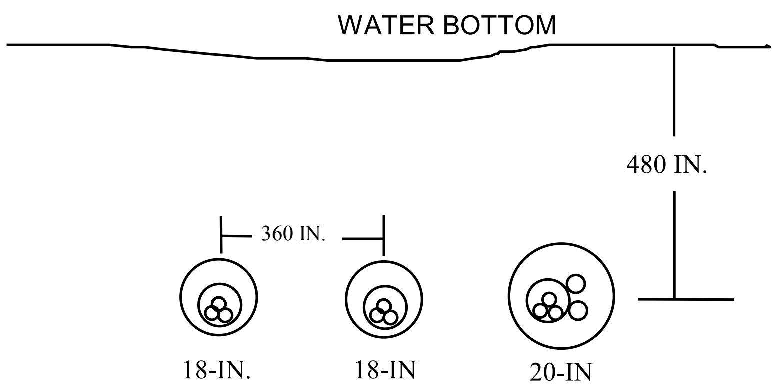

Figure 4-1. Potential cross-section of pipe-type cables in borings (not to scale)

Most of the pipe-type cables installed by guided boring in the last few years have been installed without a casing. The utilities have felt that the steel pipe itself is sufficient. An extra-heavy corrosion coating is provided – some utilities used two layers, with the outer layer considered as sacrificial during the pull. In several cases, the coating has been damaged during pipe installation. Although a cathodic protection system should protect the pipe from corrosion, we normally recommend that a casing be used.

We show a 360-in. (30-ft) spacing among bores. Ideally, a 50-ft spacing would be used to eliminate any possible chance of one boring wandering into another one during installation, but the 30-ft spacing is feasible. An absolute minimum 20-ft spacing would be permitted.

Eliminating the casing would certainly produce a smaller bore: twelve or fourteen inches versus eighteen inches.   For the Namekagon River crossing, the presence of gravel, cobbles, and perhaps even boulders in several strata would make it difficult to keep the hole open, and a casing pipe may be mandatory.   This is an important issue that would need to be addressed further, if underground cable is to be pursued as an option.

4.2 Land Trenching

Conventional land trenching would probably be employed on either side of the river, as noted above.

Figure 4-2 shows the land trench for a three-circuit HPLF pipe-type cable system.

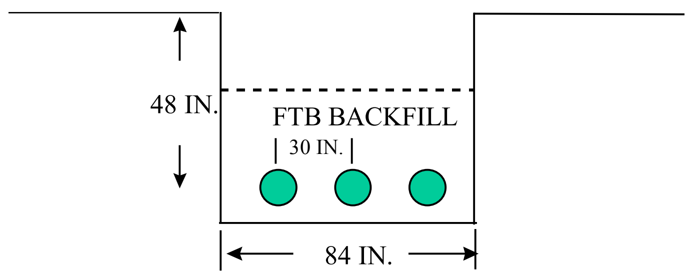

Figure 4-2.   Land trench for a pipe-type cable system.

We assumed the installation of a low-thermal-resistivity backfill, such as Fluidized Thermal Backfill (FTB) in the trench. This material is a weak-mix concrete with special design to improve heat transfer. It also provides additional mechanical protection for the cable pipes.

This trench should be kept at least 15 – 20 feet away from the trench for the oil pipelines.

5.0 CIVIL WORKS AND PIPE INSTALLATION

5.1 Guided Boring

We are assuming that, at its deepest, a bore would need to be approximately 40 feet below the river bottom, which was the depth for the Lakehead pipeline crossing. Detailed analysis may show the need to go deeper to avoid "frac-out" of drilling mud. The effect on cost and ampacity would not be major if a depth of 50 - 80 feet is chosen.

Several areas that affect the boring design and cost are summarized below:

Boring Conditions – Minnesota Power provided a drawing and boring logs from the 1997 Lakehead crossing of the Namekagon River very close to the potential cable-crossing site. We noted the following conditions:

- Borings, and Lakehead experience, showed the presence of gravel, cobbles, and an occasional boulder. These three conditions make boring difficult.
- Lakehead had a significant setback distance: the total boring length was about 880 feet, for a river crossing that is less than two hundred feet. This is necessary primarily to achieve the desired bore depth using a very gentle slope.

Lay-down Area – Once casing installation begins, it should be continued without stopping. Otherwise, the drilling mud may begin to set up, and re-starting the pull would be quite difficult.

Therefore, a lay-down area for the full 900-foot length of the boring should be established on the side of the river opposite the drilling rig. The full length of casing pipe should be made-up before installation of any pipe begins. Installing the cable pipe for HPLF cables is not as critical, but it is still desirable to install the full 900-foot section to minimize crew size and installation time. Our site visit indicated that this open length would not be a problem.

Drilling equipment and mud handling – Equipment of the size required to handle this project would require a work area of about 100 by 150 feet on the side where the drill rig is located. An area 50 by 50 feet, plus the laydown area mentioned above, is required on the opposite side. Bentonite slurry, required to cool the drilling head and remove cuttings, would require an extensive mud handing and recycling system. Excess bentonite should be disposed of properly at the completion of the job.

"**Frac-out,"** losing the drilling mud through fissures in the overlying earth, is a potential problem for any guided-boring installation. Guided boring requires performing detailed corings and soils analysis. The estimated 40-foot depth below the water bottom may have to be increased. Proper drilling mud design can reduce the chance of frac-out.

Gravel roads would be required on both sides to accommodate the heavy equipment. These roads are also required to handle the heavy equipment needed for pipe/duct and cable installation.
Cable Pipe: Three 8-5/8-inch OD, 3/8-inch wall steel pipes would need to be installed. The pipes would require a corrosion coating consisting of mastic and two layers of 0.070-inch

polyethylene tape. The 40-50 foot pipe sections have flared ends. Special backing rings are inserted prior to welding, to insure that no weld slag enters the pipe. The welds are x-rayed and dye-penetrant tested, and corrosion coating is restored over the weld areas.

Casing: Each cable pipe would need to be installed in a 12-inch diameter steel casing to provide protection during cable pulling, and to provide additional mechanical and corrosion protection.

Borings: A steel casing pipe would serve as secondary containment in the unlikely event of corrosion of the steel pipe. Using cable pipe with 3/8-inch wall thickness would further reduce the likelihood of corrosion but this should not be necessary in view of using the steel casing pipe.

We anticipate that three borings would be required, as was shown in Figure 4.1. Because of the presence of gravel and cobbles, we believe that steel casing pipe would need to be installed. Two of the borings would be 18 inches diameter, and would contain a 12-inch casing with one 8-5/8 inch cable pipe. The third boring would be 20 inches diameter, and would contain a 14-inch casing with one 8-5/8 inch cable pipe plus two 3-inch communications ducts.

If the drilling conditions were easier, it would probably be less expensive to have two borings; one 32-inch boring containing a 20-inch casing with two cable pipes and two communications ducts, and one 18-inch boring containing a 12-inch casing which would have one 8-5/8 inch cable. Note, however, that the mutual heating effect of two cable pipes in the same boring would reduce ampacity – requiring a larger conductor size which would offset some of the cost savings. One boring containing the three cable pipes might even be feasible.

The two-boring and one-boring options should be investigated further if the underground cable option is to be evaluated in more detail.

As described earlier, the three borings should be spaced at least 20 feet apart to insure that they do not touch during the drilling operation. This would also reduce mutual heating effects and provide a greater ampacity.

5.2 Land Installation

Installing the land sections would need to follow commonly-accepted practices for installing steel pipe. Several comments can be made for land installation:

For pipe-type cables, the 3/8-inch wall pipe used for a water crossing would be required for land cable, as well. It is difficult to make a transition from 3/8-inch wall to the standard ¼ inch wall anywhere other than a manhole. The 3/8-inch wall is not significantly more expensive, and it provides additional protection against corrosion.

The trench for pipe-type cables may be filled with a fluidized thermal backfill (FTB) – a material with excellent thermal properties, good flowability, and a compressive strength of a few hundred psi. This backfill gives additional mechanical protection. More importantly, the trench width can be increased to allow more of the thermal backfill, if the native soil is found to be thermally poor.

Once all of the pipe for a circuit is installed, and the trench is backfilled, the line is pressurized with air to 500 psig to assure integrity, it is evacuated, and then filled with dry nitrogen at about 10 psi until cable is installed.

5.3 Right-of-Way Requirements

Directionally-drilled Section: The total right-of-way requirement for three casings in the directionally-drilled section should be about 100 feet – the 60-ft centerline spacing for the two outside casings, plus about twenty feet either side to insure that no other construction activities damage the casings or cable pipes. The closest bore should be kept at least twenty to thirty feet away from the Lakehead oil pipeline to insure that there is no physical interference. It is very unlikely that there would be any electrical interference between the cable pipes and the oil pipes.

Land Section: The trench width is approximately 84 inches. However, a fifty-foot construction right-of-way is required to permit using trenching equipment, removing spoil, handling pipe, etc. Permanent access at least twenty feet wide is needed for maintenance and potential repair of the line. The cable pipe should be kept at least fifteen to twenty feet from the oil pipeline to minimize the chance of work on one pipe causing damage to the other pipe.

5.4 Transition Station Requirements for Cable Installation

The transition station is discussed in more detail in Section 8. Prior to cable installation, the terminal structures must be in place, and piping installed from the below-ground sections to the above-ground terminations. Special piping, known as a spreader-head or trifurcator, takes the three cables from inside an 8-5/8 inch pipe, and separates them into three 5-inch stainless steel pipes which go to the base of the terminals.

5.5 Spare Parts

Since it would not be possible to access cable in the directionally-drilled section to repair a failed cable, Minnesota Power would need to keep 3 x 900 foot sections of spare cable in stock. The cable would need to be covered with a temporary lead sheath to protect it. Two pothead assemblies, and a spare splice, should be kept in stock as well.

6.0 CABLE INSTALLATION; ACCESSORIES

6.1 Cable Installation

Once the pipe is in place, cable installation would be performed in the same manner as done on standard land installations.

Pipe-type cable installation requires special equipment and experienced personnel. There are only three or four firms in this country that are considered qualified to install HPLF cable.

Special trailers bring the 12-ft diameter cable reels to the site; the three cables are brought together and pulled into the approximately 1600-foot pipe section from one spreader-head to the splice location. Shorter sections of about 100 feet of cable are installed from the opposite-end spreader-head into the splice location. Special caps are placed over the cable ends and the pipes are pressurized with 10-psi nitrogen until splicing is performed.

A splice takes about 7 days of around-the-clock work to complete. A special splicing trailer is placed over the manhole for this duration, and provides fresh, dehumidified air during the splicing. Once the cables are spliced, steel casings are welded in place to protect the splices and contain the dielectric liquid pressure.

At the ends, the cables are prepared and porcelain terminations are placed over them. Once all splicing and terminating is completed, the line is evacuated and filled with dielectric liquid. The pressurizing plant, typically in an outdoor aluminum-walled building, is installed to accommodate liquid volume changes and pressure variations for all loading and ambient conditions. Pressure is applied to the line slowly, and after a day or two at full 200-psi pressure, the line is tested and placed into service.

6.2 Pressurizing plant:

At a minimum, one pressurizing plant would be required. The plant would be approximately 10 feet wide, 10 feet high, and 20 feet long. It would contain a reservoir tank of about 5,000 gallon capacity, a primary and backup pressurizing pump for each circuit, controls, and alarms, and a heater system. The plants are typically shipped as a self-contained unit, in a housing resembling a walk-in cooler.

For three circuits of this importance, it would be advisable to provide two plants of slightly smaller capacity, one at each end of the circuits. Since the circuits must be de-energized if pressure is lost, the second plant would provide pressure if the primary plant is out of service. Alternatively, a “backup emergency plant” which is a skid-mounted unit which has necessary pumps, controls, and alarms, can be purchased. That plant can be connected to a 5000-gallon tank truck, which would be used as the reservoir tank. A utility would typically keep the backup plant in its storeroom, ready for quick application to HPLF circuits anywhere on its system.

6.3 Cathodic Protection, Grounding

Leaks are very uncommon on cable pipes. Of the few leaks that have occurred, most of them have been corrosion “pinholes” (small areas where the pipe corrodes through the entire wall thickness). Most of them have occurred in major cities where dc transit systems are present, and the dc ground currents disturb the cathodic protection system. Nevertheless, great care should be taken to properly protect cable pipes even in rural areas. A good corrosion coating, installation procedures that minimize the chance of damage to the corrosion coating, and coating tests and repairs are the first line of defense to avoid pipe corrosion.

Cathodic protection is provided on the cable pipes to give additional protection. Without cathodic protection, current would flow from a holiday (damaged section of coating) to the earth, taking metal ions with it. With cathodic protection, the pipe is maintained at about negative 0.85 volts by sacrificial anodes or a rectifier. If there is a holiday in the coating, current would flow from the earth to the pipe – and there would be no loss of metal.

We are only considering protecting the cable pipes for pipe-type cables. It is not necessary to protect the steel casing; corrosion of the casing would cause no operational problems for the cable systems.

Cathodic protection requirements would have to be coordinated with Lakehead.

Miscellaneous: Thermocouples and other miscellaneous small accessories are typically supplied.

7.0 TRANSITION STATION REQUIREMENTS

7.1 Transition Station

A transition station would be needed on each side of the river, where the underground cable exits above-ground and connects to the overhead line. The fenced-in area may be about 160 feet by 184 feet.

All pipe-type cable installations – with very few exceptions – are installed on substation structures. Since this is a remote area, installing “bullet shields” around the terminals and surge arresters would be a strong consideration. These thick fiberglass enclosures are not attractive, but they protect the equipment from vandalism and they also limit damage to adjacent potheads if there is a pothead failure.

The transition stations consist of a deadend structure for the overhead line, a structure to support the potheads and surge arresters, a foundation and housing for the pressurizing plant (at one end of the cable circuits, at least), and a small cabinet for the rectifier and fault isolator. Disconnect switches or links must be provided to isolate a failed cable, and allow returning the two good lines to service. Current transformers are desired to help quickly determine which cable line failed. A small control building could be provided for alarms and controls, or a place could be set-aside in the pressurizing plant. A 120/208 v. distribution supply is needed for the pressurizing plant and cathodic protection system.

It is unlikely that circuit breakers would be installed in the transition station. The potential cable circuit would be a small portion of the overhead line length, therefore the line would be tripped from each end in event of a fault.

Utilities do not normally re-close on a cable fault, so the utility needs to determine whether the fault was on the overhead line or in the cable system. If the fault is in one of the cables, the disconnect links or switches are used to isolate the failed cable line (all three phases) and ground it. The line would then be re-energized from each end with the two remaining cable lines in service.

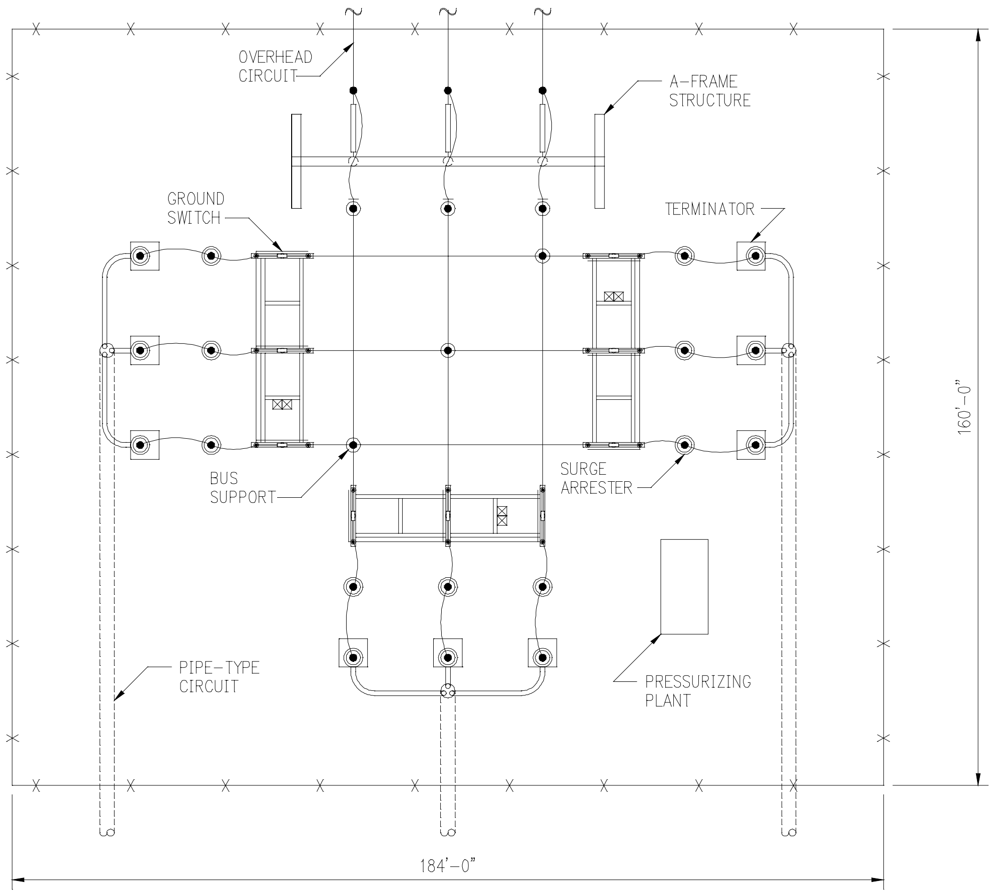

Figure 7-1. Plan view of potential 345-kV overhead/underground transition station.

7.2 Relaying

A utility would automatically reclose on the circuit if an overhead line trips, since in all likelihood the fault is a self-clearing one.

The situation is more complicated if a line trips that contains a short cable section. Cable faults are not self-clearing.

In pipe-type cable circuits, reclosing would cause additional cable damage in the area of the fault – which is not a major problem. However, if carbonized dielectric liquid migrates to other parts of the cable system, a localized repair may turn into a more extensive repair. Therefore, general utility practice is to <u>not</u> reclose on a fault when the line contains HPLF cable.

Relaying can be provided that determines whether a fault is in the cable section or not. This relaying, although expensive and requiring additional communications, gives better operational flexibility to the system operator.

8.0 ENVIRONMENTAL CONCERNS

PDC'S scope does not include environmental review of the potential transmission system. However, we offer the following general comments on installation and operation of a pipe-type cable system:

8.1 Installation

Land installation has the temporary construction impacts associated with any excavations: noise, dust, spoil disposal, potential for erosion, etc.

Directional drilling under the Namekagon River has the potential for spillage of bentonite clay, which is used in the drilling operation. There are possibilities of spills at the entry and exit locations, and potential 'frac-out' – loss of fluid into the river through fissures in the material above the bore.

Bentonite is a naturally-occurring clay and minor spills should cause no long-term effects. However, the drilling contractor should have carefully-defined spill control plans to minimize amounts of fluid that can be lost.

8.2 Operation

The magnetic fields from pipe-type cables are very low because of the good shielding effects of the steel pipe. Electric fields from a buried cable system are negligible.

Since the cables generate heat during operation, the earth above them would be slightly warmer than the surrounding earth, less than a few degrees. The only reported concern is the possibility of premature germination in field crops.

Trees would not be permitted on the permanent right-of-way. Grasses and small shrubs are generally permitted except for the access along the line for patrolling it.

Dielectric liquid leaks from cable pipes are very uncommon. The pressurizing plant should have sophisticated leak detection circuitry. If a leak does occur, it should be located and repaired quickly. Leaks should not be an issue for the directionally-drilled section since the casing pipe would shield the cable pipe from mechanical damage or corrosion, and would provide secondary containment.

The transition stations would be visible from the river and nearby areas. Pumps in the pressurizing plants would generate noise during their operation.

8.3 Repair

If a cable does fail, large equipment may be needed to make repairs. Depending upon the soil conditions, it may be necessary to place a temporary gravel or plank roadway to the repair location.

9.0 COST

PDC developed estimate-grade costs (accurate to within 20%) for potential Namekagon River crossing, as summarized in Table 9-1.

Table 9.1
Cost Summary, Possible 345-kV Cable Crossing of the Namekagon River
All costs in $1,000's

Material	Cable Installation	Civil Work	Transition Station	Mobilization, De-mob; Engrg, Supv	Total
$1,200	$550	$950	$2,850	$500	$6,050

Unit costs for major items included in the table are given below:

345-kV, 3000 kcmil cable	$55 per conductor foot
8-5/8 in. pipe	$18/foot
Trenching	$75 per trench foot
Directional Drilling	$200,000 / bore assuming three 18-in bores
345-kV terminations	$55,000 each single-phase termination
Pressurizing plant	$250,000

10.0 ALTERNATE CROSSING

PDC also visited an alternate crossing adjacent to a railroad bridge about ½ mile from the 161-kV overhead line right-of-way. This site appears less favorable for the potential cable crossing for several reasons:

- Access for the directional drilling equipment and cable pulling equipment on each side of the river would be more difficult.
- It appears that obtaining enough room to site a 160 by 190-foot transition station on either side of the river would be difficult.
- There is evidence of another recent river crossing by a different utility, that could give conflicts if the cables were to be installed in this location.

We did not perform a detailed technical or cost analysis for this potential crossing location. Based upon our site visit, we anticipate the technical difficulty to be greater, and the costs higher, than the crossing adjacent to the 161-kV line.

11.0 SUMMARY

High-pressure pipe-type cable is the preferred cable type if the line is to be placed underground. It is the U.S. standard, but contains a dielectric liquid that may cause concern for installation under a river.

The presence of cobble, gravel, and boulders, would make a guided-boring installation difficult. We are recommending a thirty-foot horizontal separation from the nearest oil pipeline. A thirty-foot separation between cable bores is recommended. This separation can be reduced, but the drilling operation would need to be slower, more careful, and somewhat more costly.

On land, a twenty-foot separation should be maintained from the oil pipeline. The construction right-of-way for the three circuits should be fifty to seventy-five feet, and the permanent right-of-way should be a minimum of twenty feet.

Installation of any cable type would mean new spare parts requirements – and perhaps changes in operating procedures for the overhead line to which the cable is attached.

Installing underground cable beneath the Namekagon River would require the construction and operation of transition stations on each side of the river. The transition stations would include pressurizing stations to maintain the 200-psi oil pressure in the underground pipe. The transition stations would be visible from the river and nearby areas and would generate noise.

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